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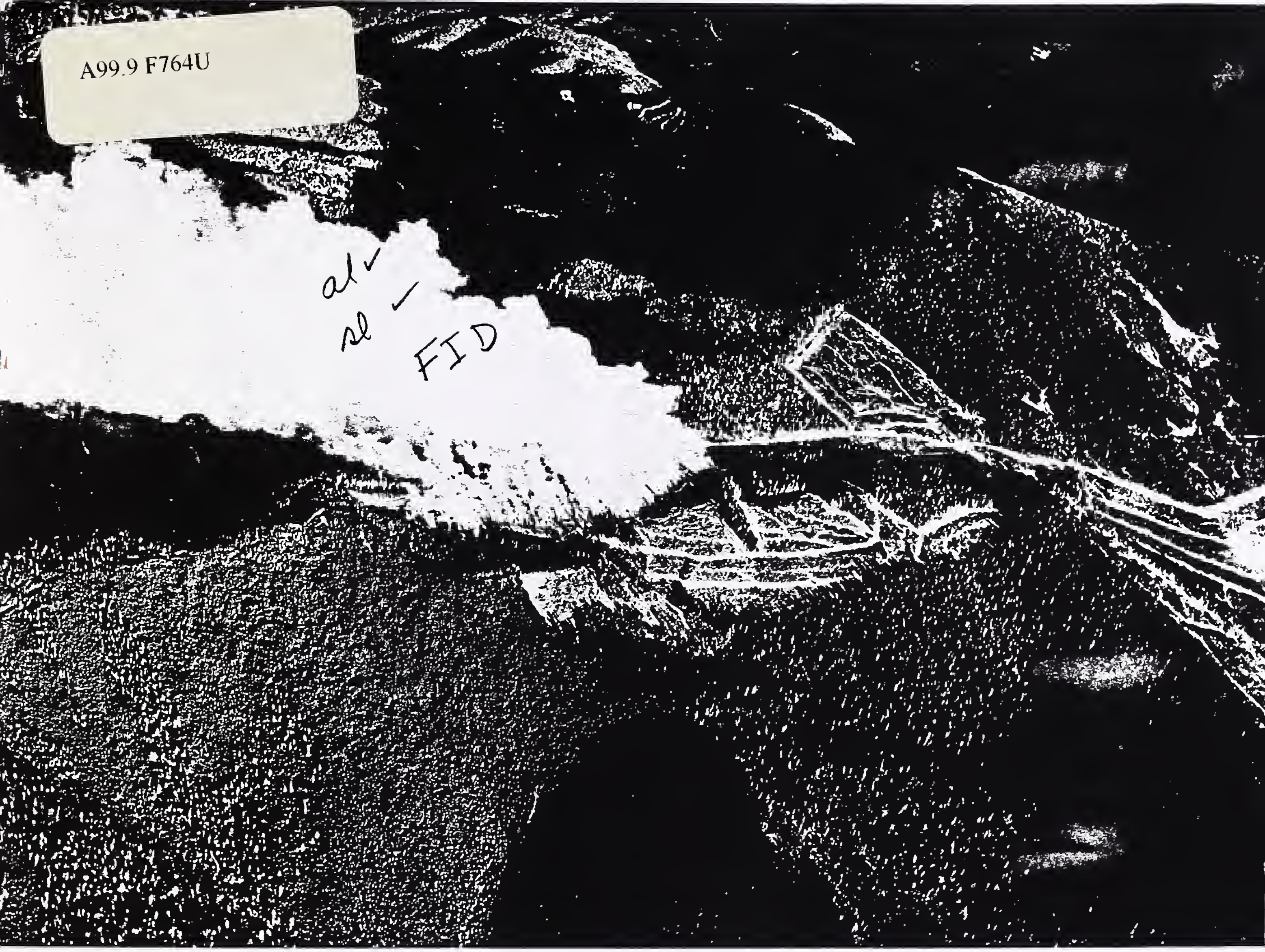

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PRESCRIBED FIRE PLANNING IN THE INTERMOUNTAIN WEST

William R. Beaufait

U.S. Forest Service
Research Paper INT-26
1966

Intermountain Forest and Range Experiment Station
Forest Service
U.S. Department of Agriculture
Ogden, Utah

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W. R. B.

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
OGDEN, UTAH
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INTRODUCTION

Prescribed fire has been used in the forests of the Intermountain West since 1910.[1] It is employed for site preparation for planting or seeding, hazard reduction, livestock range and wildlife habitat improvement, cover type conversion, and insect or disease control. The major advantage of fire for all these objectives is its low cost relative to mechanical or chemical treatments.

The use of fire is increasing rapidly as management of both private and public lands intensifies. In 1964, in Montana and northern Idaho alone, more than 25,000 acres of forest land were broadcast burned under controlled conditions. This was more than double the acreage burned in that area during 1959.

Prescribed burning is defined by the Society of American Foresters as:

> Skillful application of fire to natural fuels under conditions of weather, fuel moisture, soil moisture, etc., that will allow confinement of the fire to a predetermined area and at the same time will produce the intensity of heat and rate of spread required to accomplish certain planned benefits to one or more objectives of silviculture, wildlife management, grazing, hazard reduction, etc.[2]

Foresters new to the field require guidelines for prescribed burning. Men who have planned and administered controlled burns in the past are best current sources of such information. For this reason, 62 fire specialists from private, State, and Federal organizations were interviewed during the spring of 1965. The respondents had participated in a total of over 700 seasons of prescribed burning, mostly in the forests of the Intermountain West. The study area included the States of Idaho, Montana, Utah, western Wyoming, eastern Washington, and portions of Nevada.

The standard interview consisted of an introduction and explanation, a directed question-and-answer session, and planning hypothetical fires on topographic models. Each participant answered nearly 100 questions in the following subject areas: (1) preparations for burning, (2) scheduling the fire, and (3) ignition, control, and mopup. He designed firing plans for three hypothetical burning blocks.

Probably no opinion expressed in the following pages is the best ultimate answer to the problems of beneficial use of fire in the Intermountain West. The diversity of environmental conditions in such an area precludes any single solution. Many promising approaches to these problems have not yet been explored. In the past, prescribed burning has been done very conservatively. Until a more comprehensive background is established, it will be difficult to evaluate objectively the costs, results, or optimum procedures for prescribed fires.

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[1] *LeBarron, R. K. Silvicultural possibilities of fire in northeastern Washington. J. Forest. 55: 627-630. 1957.*

[2] *Society of American Foresters. Forestry terminology. Washington, D.C. 102 pp. 1958.*

INTERVIEW RESULTS

PREPARATIONS FOR BURNING

Prescribed fires require careful planning. The objective of a particular burn is the first consideration, and determines the procedures to be followed. Safety and effectiveness depend to a large extent upon block size, burn layout, and fireline placement. These and allied matters are discussed in the interview questions that relate to fire preparations.

Burning Objectives

Why burn? As mentioned previously, fire has a number of uses in the Intermountain West, including site preparation, hazard reduction, range improvement, and disease or insect control. Currently, the most important combined purpose of prescribed burning is to prepare sites for regeneration and reduce fire hazards in recently harvested stands of timber.

Each respondent was asked to describe a well-prepared seedbed or planting site after a burn. Nearly everyone felt that the fire should consume the duff mantle to the extent of exposing mineral soil on 50 percent or more of the area burned. Estimates on the minimum diameter of the roundwood that should remain after a fire ranged from 4 to 12 inches. Sixty-five percent of the respondents felt that a successful fire would consume all material up to about 6 inches in diameter.

Fine fuels, such as conifer needles and small twigs, create a high wildfire hazard on recently harvested blocks of forest land. Any prescribed fire, however light, that can be made to pass over such a block, effectively removes the danger caused by these fuels.

Burning to control diseases and insects or to improve livestock and wildlife range requires a variety of fire intensities. The organism or vegetative type to be treated determines the fire intensity needed. Fires used to control *Ribes* populations, for example, must be intense enough to kill existing wood stems and to stimulate germination of dormant seeds. However, the results of burning for the above management purposes are not yet as predictable as they are for site preparation and hazard reduction.

Broadcast Burning Versus Pile Burning

Depending upon terrain and silvicultural objectives, logging slash and noncommercial stems may be broadcast burned where felled, or piled before ignition.

Manpower or bulldozers are commonly used to concentrate fuels in piles or windrows in the Intermountain West. Hand labor is often employed for piling debris in thinned stands, recreation areas, and right-of-way clearings. Dozers are currently used to pile or windrow slash in some partially cut blocks and in clearcut blocks, diseased or insect-infested stands, and brushfields being converted to timber production. Bunching slash with bulldozers usually scarifies the site between the piles: mineral soil thus exposed provides a seedbed favorable to natural regeneration.

All of the men interviewed were experienced in burning piled fuels. Each respondent was asked to define the situations in which piled rather than broadcast fuels have been burned, and to give the reasons for this choice.

The pattern of responses showed that pile burning is more widely practiced in the southern and eastern reaches of the study area than in the northern and western: broadcast burning is not common in the ponderosa pine — Douglas-fir and lodgepole pine — spruce types of Utah, Wyoming, southern Idaho, and Montana east of the Continental Divide. Timber is usually harvested in small, clearcut blocks in these areas, and there has also been partial cutting in several stands. Pile burning is frequently preferable to broadcast burning for such treatments. In addition, there has been less experience with broadcast fire in these areas than in the northwestern part of the region studied. A large cadre of forest workers familiar with techniques of broadcast burning would be essential to any sizeable program in the southern and eastern portions of the study area.

Pile burning is also more appropriate than broadcast burning under certain topographic conditions that may occur throughout the study area. At high elevations, where there is a rapid transition from summer to winter, piled logging debris can be burned after snow falls — a time when scattered fuels will not support fire. At low, dry elevations, stands of timber are often not dense and may provide insufficient fuel for broadcast burning.

Mechanical procedures for piling slash are beyond the scope of this study. Two principles are worthy of note, however: (1) If slopes exceed 30 to 35 percent, machines are slow to complete the job, and broadcast burning of such blocks should be considered; (2) operators should make every effort to prevent including soil in piles of slash. Soil mixed with slash makes burning more difficult and increases the chance of holdover fires.

Several respondents expressed the opinion that any fuel worth the cost of piling was also worth covering. In some cases, specialty paper products or asphalt emulsions have been placed on the tops of piles to protect them from precipitation prior to burning. Usually only a small portion of the pile is covered. This spot remains dry enough to support combustion after rain or snow has dampened the surrounding forest.

As indicated, bare mineral soil can be exposed on any desired portion of a machine-piled area, and piles can be burned at times when unpiled slash will not support combustion. Certain disadvantages are also inherent in pile burning; for example, the costs of machine piling and burning are higher than those of broadcast burning in similar blocks, even on slopes of less than 30 percent. Most of the respondents who were experienced in burning heavy fuels of the white pine and ponderosa pine—Douglas-fir types contended that piling is economically justified only on blocks adjacent to high-hazard fuels or to other ownerships.

Some other disadvantages of piling and burning were emphasized during the interviews. Once ignited, a pile or windrow may burn for a day or more. Unless adjacent fuels are wet, the likelihood of fire escaping is increased by the extended burning time. Also, piles and windrows occupy sizable portions of clearcut blocks. A few men had noted changes in soil structure associated with extreme durations and intensities of pile fires.

Windrows are gaining in favor over dozer piles because crawler tractors can be used more efficiently and ignition crews can concentrate their efforts on fewer separate piles. Most respondents felt that windrows should follow slope contours. Contour windrowing reduces the amount of tractor sidehill maneuvering, and subsequent plowing and planting operations are not hindered by having to cross burned windrows that may contain large, unburned logs. A few others maintained that windrows should extend up and down the slope. Men who argued for the latter method listed two reasons for their stand: (1) Tractors working across the slope may do less damage to watershed characteristics than if the tracks and scraping occur parallel to the slope, and (2) ignition can be controlled more efficiently and by fewer men when windrows are burned from either the bottom or top of the slope.

Harvest operations on many forest properties are extending to higher elevations and steeper slopes than in the past. This fact must be considered in planning slash treatments. Broadcast burning may be practiced more extensively in difficult topography than heretofore, due to limitations in tractor use.

Block Size

A burning block is an area planned for complete ignition within one daily work period. It has defensible outer boundaries and may be subdivided by internal firebreaks. Areas that are piled by machine or hand prior to burning are not included in this discussion, since they need not be completely ignited on any one day.

How big should a burning block be? Answers to this question are complicated by the many variables associated with block size — silvicultural practices, topographic boundaries, protection of adjacent timber resources, watershed and wildlife considerations, aesthetic values, and manpower and equipment available for the operation.

For the present we will consider size only in terms of efficiency of ignition and subsequent control. Assuming that an area to be broadcast burned has well-located boundaries, and that all portions of the block are accessible, what are the minimum and maximum areas that can be burned easily and economically?

Nearly all of the men interviewed stated that blocks of less than 20 acres are inefficient and costly to burn. About half of these men felt that 40 acres should be the minimum size for broadcast burning.

There was less agreement on the maximum size for a burning block. Seventy-two percent of the respondents chose maximum block sizes of between 100 and 400 acres; most respondents favored 300 acres. Eighteen percent of the men gave figures of between 500 to 1,000 acres. At the other extreme, 10 percent indicated that the largest block should be between 40 and 100 acres. Men with experience in the white pine type favored slightly larger blocks than those who burned in the other forest types. An optimum block size of 100 to 200 acres was mentioned frequently.

Arguments against burning small blocks were based on the following: A fire less than 40 acres in size has a long perimeter proportionate to its area. Control problems are multiplied as the boundary between a burn and the adjacent forest is lengthened. It is difficult to manipulate the flame front and convection column on small fires in order to protect block edges. Finally, many small blocks are much more costly to patrol after burning than a similar acreage concentrated in a few larger blocks.

Manpower and control needs determine the upper limits of burn size. Blocks larger than 200 acres often require larger crews than are locally available, and importation of men and heavy equipment is expensive.

For tactical reasons an individual block should be burned as one fire with one convection column. Using present procedures and devices, it is extremely difficult to ignite large, sprawling blocks when and where necessary to make the fire behave as a unit.

Layout of Burn

Ideally, a prescribed fire should be held within its firelines. The two most common causes of escaped fires are improper block layout and unexpected winds. Winds will be discussed in a later section on burning weather. Here we are concerned with the principles of block design that insure rapid ignition and successful control of prescribed fires.

The respondents agreed that if the burning was the sole consideration in the block layout, a well-planned area would look something like this: a gently sloping circular mound completely surrounded by roads, with no steep, forested inclines directly adjacent to it. Or it might be a large patch on the face of a mountain, with its upper boundary slightly over the crest and straight edges up and down the slope; this block should narrow slightly toward the lower line.

Fire is a much safer and a more effective tool when block boundaries are located to permit burning under severe fuel and weather conditions. What, then, are the criteria for boundary location? The idealized blocks described above have most of the qualities desired by the prescribed burner. Two fire behavior characteristics are accommodated: (1) A fire normally spreads uphill, perhaps fanning slightly outward, and (2) the rate of spread tends to diminish after reaching the crest of a ridge. These characteristics also conform to the pattern a wildfire might trace under similar topographic conditions.

The nearly circular shape for a block simply illustrates another important planning principle — the greatest area is burned per chain of fireline. Circular blocks are obviously impractical in most situations, but if fireline length can be reduced without creating other hazards, there is proportionately less line to guard and patrol per acre burned. Since straight firelines are also important to the control job, the idealized square block thus becomes the best compromise between area and length of outside line. Carrying this principle a bit further, the larger the block, the greater the area that can be burned per chain of fireline.

The straighter the line, of course, the shorter the length to be defended. Any deviation from a straight upslope line tends to place fire beneath some portion of the line and endanger adjacent stands. Many fire escapes have resulted from so-called doglegs in the fireline.

Topographic features are an essential consideration in the location of a fireline. A straight block edge that transects spur ridges or draws can be as hazardous as a crooked fireline. Radiation across steep, V-shaped canyons has been known to precondition fuels facing prescribed fires until they can be easily ignited by firebrands. In the judgment of the men interviewed, it is better to include the whole of such topographic features in the cutting block or to completely exclude the threatening slope than it is to risk firing an outside stand.

Real situations are compromises between the need to conform to natural stand boundaries when laying out a timber sale, the location of logging roads, the seeding characteristics of the species to be regenerated, watershed requirements, and mountain topography unrelated to the orderly plans of man.

Fireline Construction

Once an area has been selected for burning, fireline specifications must be written. How wide should the fuel break be? How much mineral soil should be exposed? Answers to these questions are always qualified by the nature of fuels, adjacent hazards, and topography.

A fireline width of one dozer blade, or 12 to 14 feet, was considered minimal by the great majority of those interviewed. Fifteen percent of the men preferred to have 20 or more feet cleared between slash and adjacent fuels. The maximum recommended width was 1 chain.

In the Intermountain West, bulldozers used for fireline construction usually have straight blades. This means that fuels are removed from a 12-foot or wider line. However, mineral soil need not be exposed more than a few feet in width. When slash does not abut the standing timber, a narrow, hand-built line can be sufficient.

The purpose of a 12-foot-wide break in heavy fuels is to prevent radiant heat and sparks from igniting fuels outside the burning block. The narrower line of mineral soil is necessary to prevent the fire from creeping through the duff into adjacent fuels.

The respondents voiced some special cautions regarding fireline construction: First, there is a tendency for bulldozer operators to dip their blades through the duff layer into mineral soil. Inorganic soil is thus included in the duff and slash deposited inside the fireline. This mixed berm tends to burn for many days after the main fire is extinguished, creating a hazard in dry weather. As stressed in the discussion of pile burning, soil and fuel should not be intermingled.

Second, wide firelines in slash can defeat their own purpose. The fuels that are moved to construct the line must be deposited somewhere. If pushed outside the block, they present a possible control problem; spot fires that frequently occur near the block edges are difficult to extinguish in slash. On the other hand, if excessive concentrations of slash are deposited within the line, they can also be a threat to adjacent stands when burned. If firelines are widened from one to several dozer-blade widths, displaced slash can accumulate to great height along the line. To avoid this, slash from firelines should be mechanically distributed well within the block boundary. In heavy fuel it is sometimes necessary for bulldozers to push the excess slash 50 or more feet into the burn area.

Third, nearly all respondents insisted that slash should not be tolerated outside the firelines. Many cutting contracts specify that boundary trees be felled toward the block center. Treetops that do fall outside the fireline should be skidded back inside.

Logging roads frequently constitute outer firelines. It is well to plan for the disposal of slash from right-of-way cuttings inside the burning block. Care should also be taken in constructing jammer roads so that logs are not partially buried in the berm.

Some respondents recommended building all outer firelines as access roads for four-wheel-drive vehicles. They mentioned four advantages of such roads: (1) Truck-mounted ignition devices can be employed, (2) fire retardants can be more easily applied along firelines, (3) emergency use of tankers is facilitated, and (4) postfire patrol is more efficient.

Firelines, even those a chain or more wide, may not contain a fire that is poorly designed or executed. Uncontrolled convection currents containing sparks and larger firebrands are the immediate cause of most fire escapes. Firelines merely interrupt the spread of the ground fire. Fire retardants, including water, applied along particularly hazardous line segments immediately before and during burning, aid fire control efforts. While continuous firelines are essential around a burning block, control of the fire depends to a greater extent upon intelligent block design and timing of ignition.

Laydown of Snags and Noncommercial Trees

Blocks of merchantable timber contain many trees that are too small, of poor quality, or too badly decayed to be harvested economically. Such noncommercial trees, if left standing, are an obvious wildfire hazard as well as a source of infection from disease and insects. Unless they are felled during clearcut logging, a separate operation is required to drop them to the ground. Snags outside the fireline contribute to the hazard of fire escapes. Their dry and punky parts or shaggy bark can harbor intercepted sparks. For this reason, snags adjacent to burn blocks are often felled. Two questions in the interview related to the treatment of snags and noncommercial trees: What stems are dropped within the block? How far outside the line should snags be felled?

Almost all respondents felt it was necessary to lay down noncommercial trees within the block before burning. They gave three reasons for their opinion: (1) Laydown contributes to the fuels already available and tends to make them uniform and easier to ignite, (2) fires are restricted to the ground, do not crown within the burn, and reduce the mopup effort, and (3) burned blocks recover their aesthetic qualities sooner if no snags remain after the fire.

Just which trees are felled prior to burning depends upon the method of laydown. Trees and snags may be sawed, pushed over with bulldozers, or uprooted by a heavy cable stretched between crawler tractors. The first two methods are selective, the third nonselective.

Cabling must be done under moist soil conditions to ensure uprooting of residual trees. Unless the trees are both killed and laid close to the ground, they remain green and contribute little to the fire.

All respondents agreed that any snags within a clearcut block should be cut. However, the minimum size recommended for felling standing live trees ranged from 1 to 6 inches in diameter. A good compromise is that all residual trees over 4 inches in diameter at breast height be felled. On the other hand, if site preparation or type conversion is the goal, smaller trees and brush may need to be cut to provide a continuous fuel bed. If mistletoe control is called for, all trees that survive a fire should be felled. A few men felt that laydown was necessary only within a few chains of the block boundary.

Outside the fireline, shaggy-barked or rotten-topped snags should be felled whenever they occur within 1 chain of the line, or when they are not screened by green vegetation in surrounding stands. Laydown should follow the harvest operation as closely as possible; burning is more consistent and effective when both slash and laydown retain their needles. However, old slash without needles can be made more flammable by recently cured laydown.

SCHEDULING THE FIRE

When should burning be done? Prescribed fires in the Intermountain West have been attempted under almost every type of fuel and weather condition, and slash piles have been burned while covered with a mantle of snow. A few prescribed fires have been ignited during a lull in the summer wildfire season.

The purpose of burning determines the time of burning, since a wide range of fire effects can be produced by varying the burning date. The respondents had very little experience in the planning and execution of burns during dry, warm periods, and only a few men had burned prescribed fires in the spring. Opinions presented in this section should be interpreted accordingly.

Age of Fuels

Slash and laydown fuels usually must be cured before they will burn. Curing is indicated by needles that have begun to turn yellow, red, or brown. If trees are allowed to remain on a site too long after cutting, however, the needles and fine twigs will fall to the ground. Within a few years only large stems and branches remain elevated above the duff. Fuels that are either too green or too old are difficult to ignite, burn poorly, and may not generate enough heat to accomplish the desired objectives.

The men interviewed considered 1 to 2 summer months the minimum time required for curing of fresh slash or laydown. The only exception noted was that some dozer piles of lodgepole pine in western Wyoming had been burned successfully within a few days after the live trees were uprooted. Late autumn slash may not be completely cured by next spring. Dry, warm weather is essential to cure green material adequately.

All respondents agreed that broadcast burning is easier and more effective if most of of the needles are still attached to the limbs of slash and laydown. The optimum time for burning is within 1 year of harvest. If more than 3 years elapse after logging, the primary burning objectives are rarely fulfilled. Hazard reduction goals, in particular, are not fully realized if slash remains on a block for much longer than it takes to cure.

More latitude is available in the burning period for piled or windrowed slash. Greater fuel-moisture content can be tolerated in closely arranged fuel elements, although higher heat inputs are required for ignition.

Broadcast burning is of increasing importance in conversion of brushfields and improvement of wildlife habitat. A few brushy sites have been burned in the northern reaches of the study area. Phytocides, especially in oil emulsions, were sprayed on these sites prior to burning. The purpose of spraying was to kill the aerial parts of brush stems, thereby promoting their desiccation and conversion to available fuel.

Nine of the men interviewed had some experience with spraying and subsequent burning of brushfields. They felt that brush should be sprayed in preparation for burning soon after it is in full foliage in the spring, and burned the following autumn. Or, the brush can be sprayed a week or two prior to burning, leaving dead leaves suspended on the branches to enhance the rate of spread.

Season of Burning

Although most prescribed burning in the Intermountain West is scheduled in autumn, fire specialists should consider other seasons as well; this is an important factor. To understand it better, we must know the typical sequence of fire weather in the region. Most of the timbered elevations are covered with snow from early December until sometime in April. Warm, dry weather often follows, and persists until a rainy period occurs in June. At elevations below 6,000 feet there are usually a few days or weeks during May and early June when slash or brush can be broadcast burned. July and August often bring extended periods of hot, dry weather. Sometime during the latter part of August, moist air masses begin to enter the region from the northwest. These cause precipitation that signals the end of the major wildfire season.

Most prescribed fires are scheduled sometime between late August and early November after a specified amount of rain has fallen. Relatively few burns have been conducted in spring and summer. With an increasing acreage needing fire treatment each year, fire specialists are seeking means to extend the prescribed burning period.

When to start autumn burning depends on how much precipitation in August and September is needed before the first match is struck. The answers to this question were distributed as follows:

Minimum precipitation	Responses
(inches)	(percent)
0 - 0.4	36
0.5 - 0.9	26
1.0 - 1.9	32
2.0+	6
Total	100

As indicated above, over half of the group recommended that burning begin before 1 inch of rain had fallen in the early autumn and more than one-third preferred less than one-half inch of rain. A few men were satisfied with one-tenth inch of rain or less.

Fires conducted after only a small amount of rain has fallen are easier to ignite, control, and mop up than those burned later in the autumn. Also, burning under relatively dry conditions results in better site preparation. Fewer hangover fires, more complete control of the convection column, and greater economy are other reasons given for early autumn burning.

North and east aspects and blocks at high elevations should be broadcast burned before those on lower, and south- and west-facing slopes. Piles and windrows of slash should be ignited later in the autumn. When more than a few hundredths of an inch of rain have fallen, slash needs some drying before it can be ignited. As the autumn season progresses and the days become shorter, dew and frost retard diurnal drying, and progressively longer drying periods are required after each rainfall. Ultimately, burning activity ceases as fuels become saturated. The maximum amount of precipitation after which prescribed fires can be scheduled varies with the intervals and drying conditions between storms.

No respondent was able to specify just when the autumn burning season should end. The dates of the last fires are largely dictated by the moisture in the fuel. This topic will be discussed in a later section.

Though the bulk of prescribed burning takes place in autumn, there have been several recent attempts to utilize the spring and summer seasons. The 30 men who favored some spring burning felt that these fires should be scheduled before the usual June rains. They suggested south slopes at low elevations as most appropriate for spring fires. One advantage of burning during this season is that adjacent stands may be too wet to harbor sparks from the fire. The most frequent objection to spring burning was that moist, rotting logs and duff within the burning block might smolder for days or weeks after a fire unless thoroughly mopped up.

Only one prescribed summer fire was discussed during the interviews, though many participants expressed an interest in the potentials of this season. There are a few periods during a typical summer in which fuel and weather conditions are similar to those of early autumn. About half of the respondents prophesied future exploitation of certain summer burning periods.

Time of Day

Within any 24-hour period, fuel and weather conditions vary enough to influence the conduct and control of a prescribed fire. A good planner uses diurnal variation as he does seasonal change in scheduling his fires.

About half of the respondents preferred to burn in the late afternoon, when relative humidity is rising. Reasons given were that the fuels had dried as much as possible, the wind had usually reached its peak velocity and was diminishing, and burning extended into the relatively cool, moist evening when control problems are minimized.

Others were staunch advocates of early morning fires begun as soon as fuels would ignite. These fires were planned to have the block well burned out before the heat of the day. Low wind velocities and daylight working periods were cited as primary advantages of morning fires. Those who favored such timing were working in central Idaho and east of the Continental Divide in Montana, where afternoon winds are strong and persistent.

It is necessary to adjust ignition time as autumn progresses. A morning burner might begin the season by lighting slash at 0600 and end the season by igniting at noon. Similarly, a confirmed afternoon burner might start early season fires at 2000 hours and ignite fires at the end of the season at 1400 hours. Some advocates of morning fires preferred to burn out firelines the evening before they began igniting internal fuels. The men who proposed burning in summer or in early autumn, with little precipitation, recommended that these fires be conducted at night.

Special precautions should be taken for crew safety during night burning hours. Limited visibility requires more elaborate communication arrangements than are necessary for daylight operations. The administrative problem of adjusted workdays is another common difficulty in scheduling prescribed fires, although burning hours should of course be determined by the job and not the clock.

In late evening and early morning ignition, it is important that fuels be sufficiently dry for rapid consumption. If slash lit in the morning is not consumed, a hazardous midafternoon reburn is possible. On the other hand, fine fuels respond quickly to high evening humidities especially after dark. Misjudgment of an hour or two in evening ignition time can result in an incomplete burn and control difficulties the next day.

Variation in topographic aspects and slope positions within a block further complicates timing of ignition. Fuels at the bottom of a moist draw must usually be ignited during a warm part of the day. Upper slopes exposed to sunlight can frequently be burned in the early morning or late evening.

The time of day for burning as well as the time of year merely represent expected fuel and environmental conditions. These conditions are always of primary concern to men who use fire.

Fuel Moisture Content

For the past 30 years, standardized ½-inch fuel sticks have been used as analogs of fuel moisture. Moisture content is measured by weighing the sticks with portable scales. When located in or near prescribed burning blocks, the sticks are a valuable means of approximating the moisture content of slash fuels of comparable size and exposure.

To be significant, fuel moisture estimates must be compared with the results of burning. Unfortunately, there is no widely accepted objective measure of burn success. Despite this limitation, enough prescribed fires have been conducted in the Intermountain West to permit rough assessment of the conditions under which fires escaped control or would not burn well. Through a process of trial and error, experienced burners have concluded that a certain range of moisture content in fuel sticks is likely to represent an acceptable burning condition.

More than three-fourths of the respondents were willing to attempt fires when fuel sticks in the slash block showed between 6- and 15-percent moisture content. A few others would ignite slash when fuel sticks indicated 4- or 5-percent moisture content. Two men would not start fires until the fuel sticks indicated over 16-percent moisture content.

A large proportion of respondents did not install fuel moisture sticks in the forest adjacent to their burning blocks. Of the 14 men who did, 10 wanted the sticks under a forest canopy to indicate a moisture content 2 to 10 percent greater than that of sticks located in the slash. The other four men had found that such a difference rarely existed.

Relative Humidity

The amount of water vapor in the air greatly influences the moisture content of dead organic fuels. Needles and fine twigs respond within an hour to changes in humidity. Larger pieces of slash require days or weeks to adjust to variations in humidity.

Respondents were asked what they felt minimum and maximum relative humidities should be at the start of a broadcast burn. The responses were:

Relative humidity (percent)	10-19	20-29	30-39	40-49	50+
Minimum (percent responses)	27	47	22	3	1
Maximum (percent responses)	- -	3	36	36	25

Seventy-four percent of the men interviewed said they would ignite broadcast slash when the relative humidity was below 30 percent. Only 25 percent of the respondents were willing to begin burning slash when the relative humidity exceeded 50 percent. If we take a consensus, the most acceptable condition for prescribed burning is from 20- to 50-percent relative humidity.

Relative humidity is not static during a fire. A number of experienced burners install hygrothermographs along with rain gages and fuel moisture sticks in clearcut blocks for a week or more prior to burning. They highly recommend this practice to others who schedule prescribed fires. Used in conjunction with spot weather forecasts, hygrothermograph records help predict at what time of day the desired humidity will be reached on a given block.

A few men indicated that sunshine affected both humidity and the flammability of slash fuels. When burning conditions are borderline, the sun's rays can make the difference between a fire that burns continuously and one that merely smolders when ignited.

Sunshine both directly and indirectly increases fuel and air temperatures. The fuels and the soil surface intercept solar rays, are warmed by them, and in turn warm the air. Heating the air reduces relative humidity. When the sun's rays no longer strike the fuel bed, air temperature decreases, causing an increase in relative humidity. This increase and the lack of radiant heat from the sun combine to reduce the flammability of the slash and can have a pronounced effect on goodness-of-burn.

Wind

Prescribed fires are significantly influenced by daily and seasonal changes in the velocity and character of winds. Basically, windspeed determines the rate of spread of a fire. However, there are two kinds of air movement associated with all fires: a roughly horizontal surface wind, and a fire-induced combination of horizontal and vertical convective airflow.

Early and late in a fire, normal surface winds may overpower the effects of rising, heated air, and disperse the convection column. At the peak of energy release from a fire, air may flow from all directions into and upward from the center of combustion, scarcely influenced by surface winds.

Experienced prescribed burners, aware of the different effects of each kind of airflow, consider them when developing burning plans and use them as tools in conducting fires. Winds determine to a large extent the course of control and how much the fuel or duff is reduced. The interview question was asked: How much surface wind is desirable?

Sixteen percent of the respondents preferred to have some wind at the time of ignition because it indicates direction and facilitates planning. These men also believed that broadcast fires and piles would burn more completely with wind. The remaining 84 percent preferred to burn plots when the air was as calm as possible, while recognizing that still days are rare. Some men who practiced east of the Continental Divide complained that relatively high winds almost always existed during their burning seasons. The maximum wind velocity beyond which the group would not burn was:

Maximum velocity (m.p.h.)	5 or less	10 or less	15 or less
Percent responses:	21	65	14

Recent research findings may help clarify the effects of surface wind on rate of spread and goodness-of-burn. In laboratory tests with needle fuels, rate of spread increased with rising windspeed. As rate of spread increased, the intensity of the fire lessened on any given area.[3] These tests suggest that a fast-moving fire consumes less of the available fuel than a stationary fire.

On the other hand, slow rates of spread, characteristic of low or no-wind conditions, often require closely adjoining ignition lines. Many ignition lines are desirable for greater control of the convection column, but they may also require more ignition-crew manpower. Yet managing the convection column by careful addition of areas of fuel is usually easier than trying to overcome the effects of a strong surface wind.

A single, strong convection column is desirable in that it helps overcome the influence of steep slopes and surface winds. If more than one convection column is permitted to develop, they may interact to produce large fire whirls. During the early phases of a fire, every effort should be made to build a single, strong column. Later, when the entire block is ablaze and has begun to burn out, interacting columns cannot always be avoided.

General Weather Conditions

What kind of weather is best for autumn burning? Should it be clear or cloudy — or warm or cool?

Eighty-six percent of the respondents preferred clear skies on the ignition day. Some of these men added such descriptions as "crisp, cool, bluebird weather," and a day "when smoke rises straight up." Three experienced men went to the extent of recommending an unstable atmospheric condition. On the other hand, eleven percent of those queried wanted the skies to be overcast; a few even specified low-hanging clouds and humid weather. There was no clear expression of the air temperatures most favorable for burning.

Clear weather in the autumn usually coincides with high surface barometric pressure. This condition, combined with small differences in pressure aloft, produces only light winds. Also associated with such a system are vertical temperature profiles, which in autumn afternoons tend to permit the development of strong, straight convection columns. At night, inversions in mountain valleys trap moisture and smoke close to the ground. The following morning the sun heats the ground, drying the fuels and clearing the air.

Autumn also brings cold frontal systems that cause periods of higher winds and showers. Clouds may persist for a day or so after a front has passed. Stable air profiles during the latter times dampen convection columns. There are, of course, many varieties of intermediate patterns in the Intermountain West.

If we accept the need for a strong, central convection column, a clear day with low wind is best for burning. The occurrence of inversions explains why early morning ignition is difficult to achieve on many blocks.

There is an obvious need for accurate, localized prediction of weather conditions likely to affect a fire. Specialized fire-weather forecasts are prepared upon request for individual prescribed fires, and can be obtained through U.S. Weather Bureau offices. Most respondents made use of these special forecasts.

IGNITION, CONTROL, AND MOPUP

Ignition and control procedures vary widely depending upon burn objectives, environmental conditions, and available manpower. It is therefore impossible to develop a standardized, step-by-step outline of how to manipulate men and equipment on a prescribed fire. Indeed, experienced men start burns with the expectation that many of their plans will be altered during the course of the fire. Though ignition schedules and control methods should be clearly formulated well in advance, all plans should be flexible in order to meet unexpected changes in weather or fire behavior.

The chapters on prescribed burning in

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[3] *Anderson, H. E., and Rothermel, R. C. Influence of moisture and wind on the characteristics of free-burning fires. Tenth Internatl. Symposium on Combustion. Cambridge, England. 10 pp. 1964.*

Davis' text[4] should be required reading for all who plan fires in the Intermountain West. While outlining several ignition methods, he insists that "The trained judgment of good personnel is an essential that cannot be imparted in any textbook or manual."[5]

The following sections deal with tools and techniques of general application to prescribed burning — not with specific judgments that must be made in the field.

The Plan

Each respondent contributed his ideas on prescribed fire plans. The suggestions are summarized below.

First, an adequate map should be prepared for each burning block. The scale is not critical if all topographic and cultural features are clearly shown. Some men prepare overlays for their maps, upon which they plot the location of skid trails, jammer roads, ignition lines, fire control equipment, and crews. These maps are essential on complex prescribed fires.

An experienced man can sketch a map of proposed ignition lines from a vantage point on or near the block. One imaginative respondent suggested that the planner close his eyes after sketching the map, ignite the fire in his imagination, watch it burn, and then make adjustments in the pattern. Similar techniques are used by chess players and military planners. To repeat, flexibility is essential.

Placement of ignition and control crews should be clearly indicated on the map. Some fire specialists mark crew stations on the ground as well as on the map. Numbered signs, corresponding with numbers on the map, should be placed at key points on the block to designate ignition lines and placement of equipment. These signs are also useful in directing the movement of men and vehicles before and during the fire. The sequence of ignition is usually outlined on the map and in accompanying written plans. Escape routes for men and vehicles should be clearly marked; logging roads may be numbered for this purpose.

The plan should provide for dissemination of fire intelligence. This begins with a complete briefing of the entire crew before stations are taken. Ideally, the briefing should take place at the point overlooking the block that will later serve as command post for the fireboss. Key points on the map and ground should be identified and the ignition sequence reviewed. Mopup duties may be tentatively outlined. Above all, emergency lines of retreat must be assigned to each crew.

Portable two-way radios and loudspeakers are good communication tools on prescribed fires. Radios should be assigned to scouts, sector bosses, ignition crew foremen, and operators of heavy equipment. Portable loudspeakers can be used to broadcast instructions from the fireboss. He should also have some direct means of communicating with his headquarters in order to receive special fire-weather forecasts.

Finally, the plan should outline mopup and patrol activities. The investment of men and time in postfire action depends upon how well the block burned, spot fire occurrence during the fire, and subsequent weather conditions. Because not all of these factors can be predicted in advance, planning for mopup and patrol is necessarily sketchy. However, all of the men interviewed advocated patrol after prescribed fires, and about half of them recommended mopup operations around the edges.

Ignition Devices

Proper ignition devices should provide rapid, controlled lighting of lines of fire along predetermined routes. The success of the burn frequently depends upon the speed and efficiency of ignition crews. Crews should be equipped with ignition devices best suited to the fuels and working conditions on different blocks. For this reason, a variety of devices should be on hand.

Ignition devices currently employed include matches, fusees, propane torches, drip torches, and pressurized diesel flamethrowers. Flamethrowers consist of both backpack and truck-mount types. Very pistol flares, thermite grenades, and sausages filled with jelled petroleum products are also useful.

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[4] *Davis, K. P. Forest fire — control and use. New York: McGraw-Hill. 584 pp. 1959.*

[5] *Ibid, p. 511.*

Beaufait, William R.

1966. Prescribed fire planning in the Intermountain West. U.S. Dep. Agr., Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah. 27 pp., illus. (U.S. Forest Serv. Res. Paper INT-26)

This paper presents the combined judgments of 62 fire specialists on how and when to burn logged-over forest land in the Intermountain West. Participants planned three hypothetical burns in accordance with specified objectives and environmental conditions.

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To identify the kinds of devices favored by burners in the various forest types, all interviews included the question: What ignition tools do you prefer for starting prescribed fires?

Though backpack propane torches were mentioned more frequently than any other, no one device was the choice of a clear majority. Truck-mount diesel flamethrowers are gaining in popularity in the white pine type, and there is increasing use of pressurized-tank diesel units in the southern reaches of the study area. The advantages and disadvantages of the various devices are summarized below:

Ignition device	Advantages	Disadvantages
Matches	Always available in quantity	Require fine, dry fuels
	Rapidly dispensed	Localized ignition
		Poor in wind
Fusees	Light in weight, convenient	Require fine fuels
	May be extended on pole	Localized ignition
	Hot, concentrated flame	No residual effect
	Relatively long-burning	
	May be thrown	
Propane torches (backpack)	Very hot flame	Heavy and awkward
	Long burning	Time-consuming refill
	Maintain own pressure	Refill can be hazardous
	Good for piled slash	No residual effect
Diesel flame-throwers (truck-mount)	Long residual flame	Restricted to near roads
	Long burning	Require gasoline pump
	Fast roadside ignition	Require large quantities of fuel
	Wide ignition pattern	
Diesel flame-throwers (back-pack)	Residual flame	Heavy and awkward
	Easy refill	Require pressurizing
Drip torches	Residual flame	Need frequent refills
	Light and portable	
	Fast igniting	
Very flares and thermite grenades	Some residual effect	Relatively costly
	Remote ignition possible	May burn too hot for slash ignition
Jelled petroleum products in sausage casings	May be ignited with fuse	Require presetting
	Good for piled slash	
	Persistent flaming	

Many other fuels and devices have been used to start prescribed fires. Some of these, such as gasoline blow torches, are hazardous to personnel; others, such as diesel-soaked sawdust, require separate ignition action.

Spraying slash or brush with diesel fuel from helicopters or ground-based pumpers prior to ignition has been tried on a small scale. This treatment promotes burning of green, moist, or scattered fuels.

Ignition Patterns

Where a prescribed fire is ignited is often as important to its success as *when* it is started. The system of planning described earlier, wherein the block is burned first in the mind of the planner, works well if the principles of fire behavior in slash are well known and can be visualized in the field.

When large quantities of heavy fuels burn, a buoyant action is imparted to the atmosphere above the fire. Air from all sides moves into this area of reduced pressure. As described earlier, when the upward movement of heated gases is strong enough, it can overcome the effects of light surface winds or adverse slopes.

If a block is ignited in many places simultaneously, the whole fire burns fiercely in place, not affecting or being affected by its surroundings. This extreme case is called a fire storm. If only one line of fire at a time is started in slash fuels, the flames and convection column are greatly influenced by both slope and wind.

All ignition procedures are based on the foregoing characteristics. There are three basic ignition patterns: area, internal, and strip. Each man interviewed was asked which of these patterns he used in his prescribed fires.

None of the respondents used area or simultaneous multiple ignition. Internal or center ignition was practiced primarily by men with experience in the white pine type. Men who burned steep slopes generally preferred to ignite in strips, starting at the top of the block or on the downwind side. Respondents who held to strip burning alone had rarely attempted internal ignition, but men who preferred internal firing patterns often used strip ignition on steep slopes.

Of those who specified internal ignition, the question was asked: On how steep a slope can center firing be effective? The answers ranged from a 10- to a 60-percent slope, with an average of 30 to 35 percent.

Several respondents mentioned an effective combination of strip and internal ignition patterns, in which lines of fire 50 or more feet below the uphill firelines are started prior to ignition of the extreme upper edge. When the internal fire becomes intense enough to draw air from above, the outer perimeter is ignited. Thus the flames at the top sides of blocks on relatively steep slopes can be directed inward. This technique is often faster and safer than a single backing fire from the outside firelines. However, it only applies where peripheral ignition is normally indicated.

Controlling the Fire

Most prescribed fire plans call for ignition crews and holding crews backed up by tankers, water pumps, and sometimes bulldozers. Depending upon the size and potential of the fire, the total manpower needed may range from 6 to 60 workers.

The control needs of each fire should be carefully assessed during the planning period. Potential escape points should be sought out and, if possible, corrected. Each danger spot must be evaluated in terms of the number of men and pieces of equipment required for containing the fire.

Most men felt that crew size should be determined by fire size and potential for trouble. However, about half of the respondents admitted that crew size varied little from the number of men usually assigned to brush disposal activities. In other words, the same sized crew, usually 10 to 12 men, is sent to most of the prescribed fires scheduled by a given administrative unit. Most planners wished for greater flexibility in crew size from block to block.

Blocks are often burned in small patches when larger than normal fires are scheduled. Sometimes portions of a block are burned on successive days. Thus the actual size of the crew frequently determines the manner in which a block is burned. This situation occurs most often on blocks up to 100 acres in size. On really big blocks of 200 to 400 acres, the fireboss routinely asks for assistance from neighboring administrative units, logging crews, or protective associations.

Respondents agreed that most escapes were caused by wind and consequent spotting outside the fireline. When asked how this might be prevented, the almost unanimous response was "through better block layout." Hot fires with strong vertical convection columns also greatly reduce control problems. Regular patrol was recommended to avoid postfire escapes.

The most experienced burners were relaxed in their attitudes toward escapes. Their opinions can be summarized by the statement, "Don't drop the torches once ignition begins!" This means that continuing the ignition pattern minimizes the effects of fires that have spotted over the firelines. Or, in other words, if the ignition crew drops its torches and joins with the control group in fighting an escape, the original fire may lose its drawing action or spread contrary to the firing plan.

It is not necessary here to describe how escapes of prescribed fires should be fought. Most burn planners have had experience in the control of wildfires, and there are many references that explain firefighting methods in great detail.

The majority of control problems can be avoided by intelligent layout, scheduling, and ignition of fires. With reliable weather forecasts available, escapes need rarely occur. If they do, odds are that the cause will be unexpected surface winds. Control crews and equipment are usually assigned to prescribed fires for these emergencies. The men and equipment used to control a fire are a form of insurance; their numbers and cost are the premiums paid.

HYPOTHETICAL FIRES

The final portion of the interview involved the planning, ignition, and control of fires on three hypothetical blocks. Plaster models represented the topographic positions and outlines of the three burn areas. We asked respondents to plan for broadcast burning of the blocks as though the fuels and burning conditions were typical of the forest type of their experience. As each man located firelines, placed equipment, and laid out ignition lines on the models, the interviewer sketched identical details on corresponding topographic maps. A total of about 150 such maps provided the data for this section.

The models are illustrated in figure 1. Areas surrounding the individual burning blocks theoretically support stands similar to those harvested. All noncommercial stems are assumed to be felled, and cut fuels to be one summer season in age.

Figures 2, 3, and 4 each consist of three parts — a photograph of one of the models and two topographic maps. The photograph gives perspective to help interpret the maps. Respondents were informed that the models had considerable vertical scale exaggeration and were asked to assume the steepest slope to be about 60 percent. All other slopes are proportionately less.

The topographic maps and symbols are generalized representations of the plans made by the participants. The maps should not be interpreted as exact reproductions: many details of the ignition lines have been omitted to avoid confusion. When an ignition line parallels an internal road, it usually means that both sides of the road were ignited.

On all of the maps, the numbered ignition lines begin with the tail of the arrow and end with the head. Intermediate arrow points show the direction of travel.

The number and placement of pieces of equipment should also be freely interpreted. Every actual burning block is different. These hypothetical situations are presented to illustrate principles, not details.

Block I

The topographic maps in figure 2 show the two ignition patterns recommended by respondents for the first model. Figure 2B represents the plan favored by three out of four of the men interviewed. It is a straightforward center ignition pattern with successive increments of fuel added from all sides. The domelike topography and locations of logging roads lend themselves well to a center-fired plan.

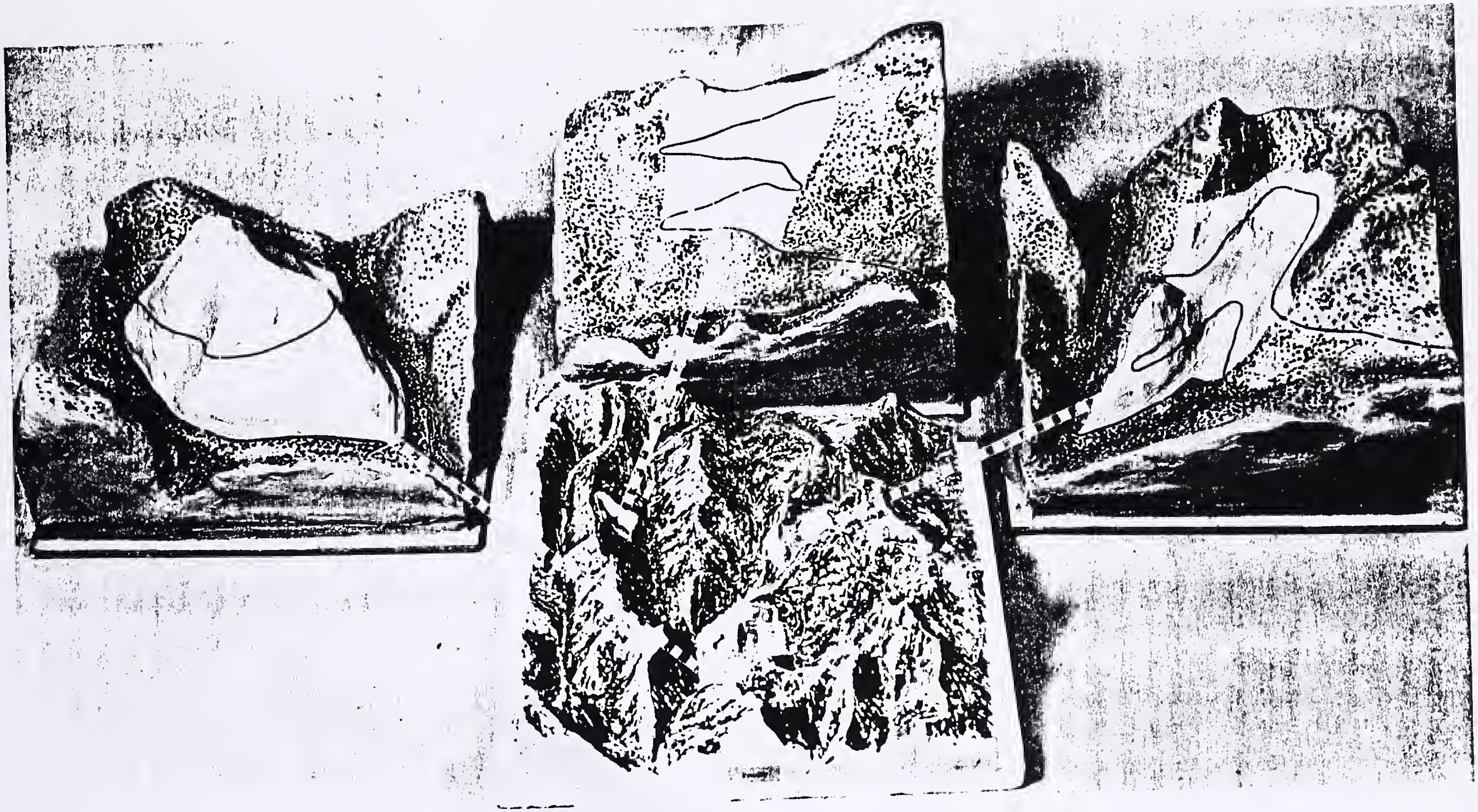


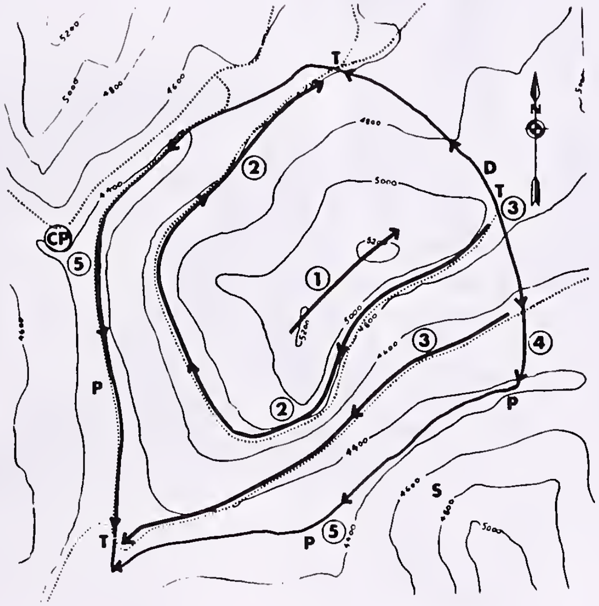
Figure 1. — Topographic models shown to interview subjects. The lower model shows overall terrain features. Each of the upper models contains a hypothetical burning block. Black lines on the blocks represent logging roads.

2A

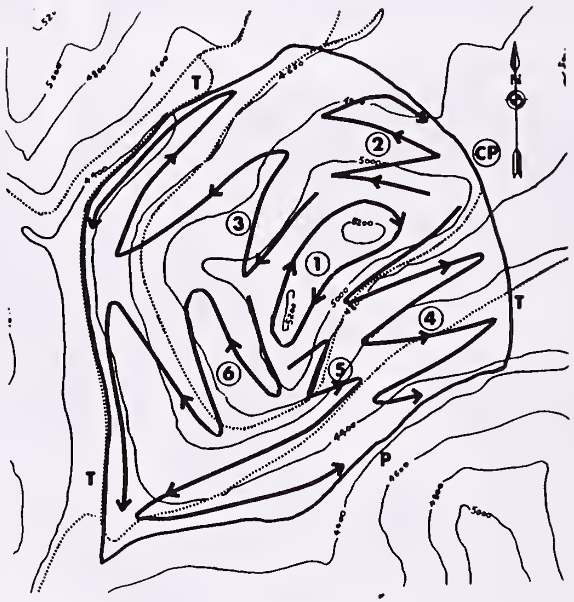
Figure 2. — Block I is about 120 acres in area.

Legend:

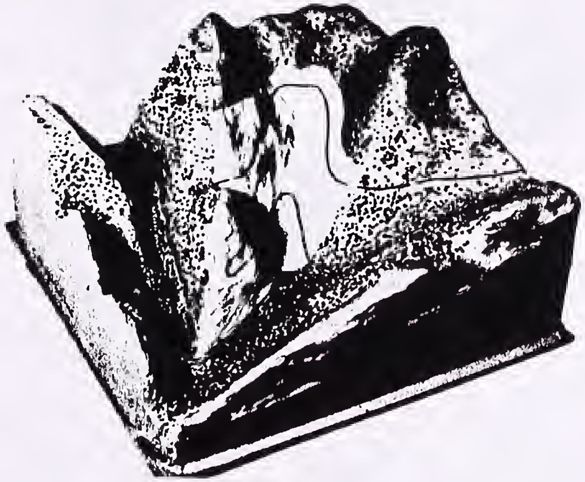
⟶	Ignition lines
⋯⋯⋯	Roads
CP	Control point
T	Truck-mounted water tanker
P	Streamside water pump
S	Scout
D	Bulldozer



2B



2C

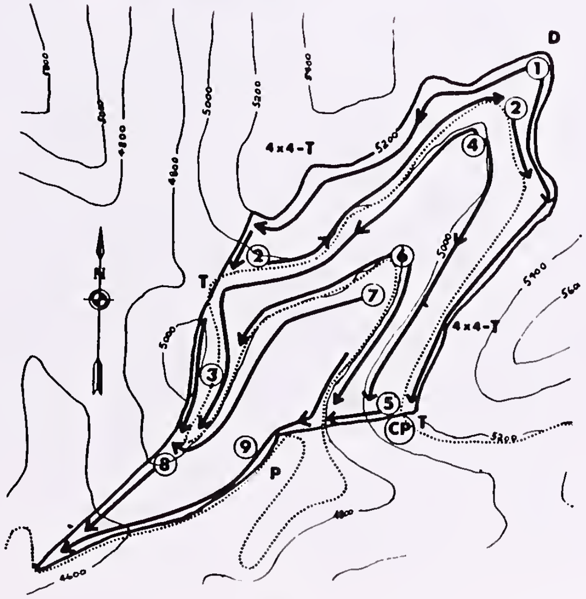


3A

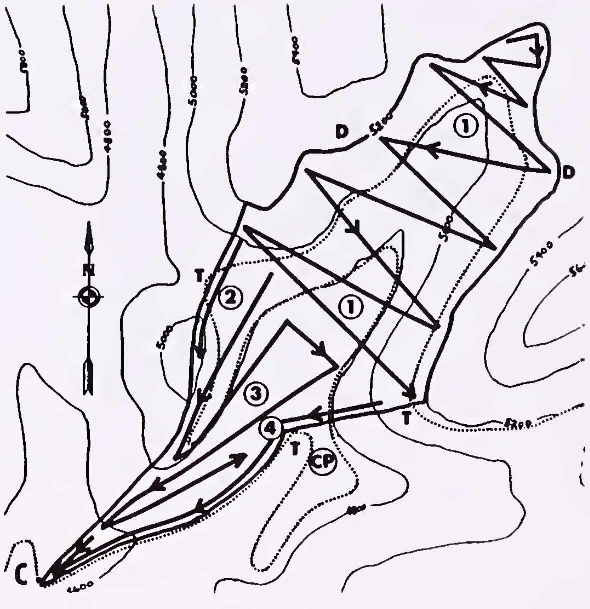
Figure 3. — Block II is about 80 acres in area.

Legend:

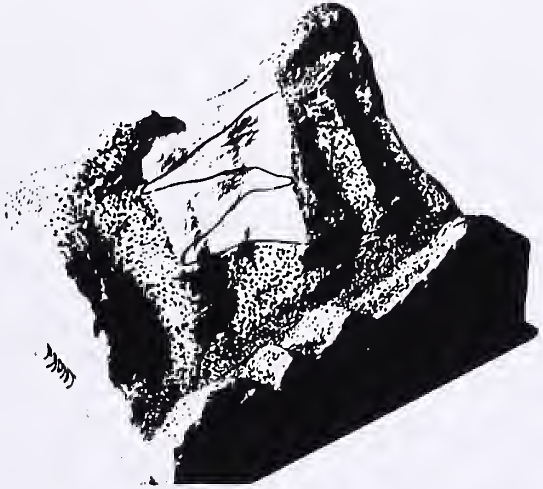
⟶	– Ignition lines
········	– Roads
CP	– Control point
T	– Truck-mounted water tanker
P	– Streamside water pump
S	– Scout
D	– Bulldozer



3B



3C

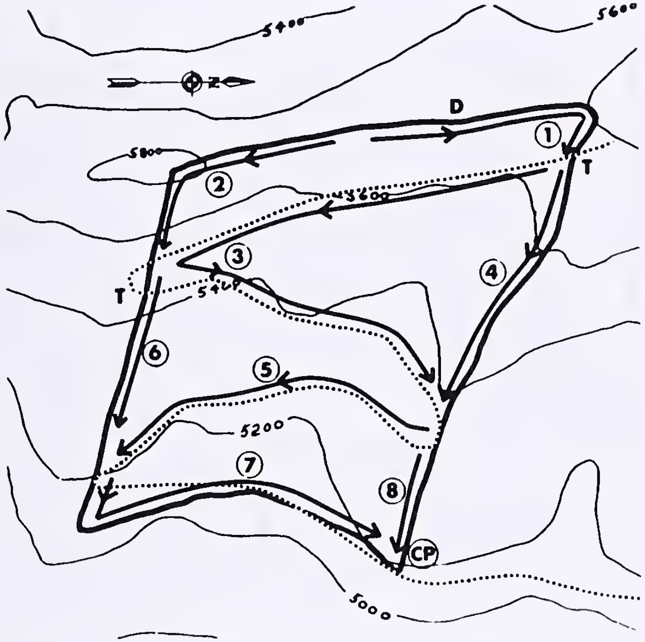


4A

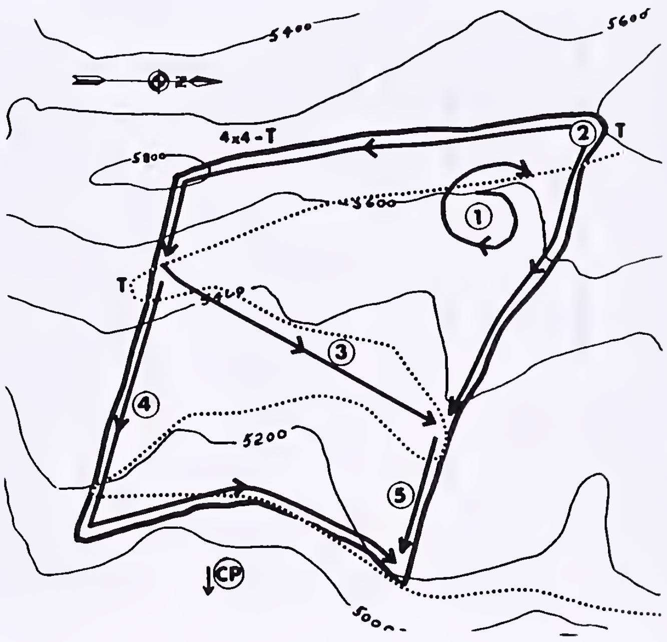
Figure 4. — Block III is about 40 acres in area.

Legend:

——→ – Ignition lines
········ – Roads
CP – Control point
T – Truck-mounted water tanker
P – Streamside water pump
S – Scout
D – Bulldozer



4B



4C

Ignition lines numbered 4 and 5 and a portion of lines marked 3 on figure 2B coincide with the block boundaries. Two crews are needed to ignite the lines marked 5. These crews proceed simultaneously down-canyon from the northern and southeastern extremities of the block.

Respondents recommending plan 2B specified three tank trucks, one bulldozer, and three water pumps located as shown on the map. Note that the control point, or position of the fireboss, is across a drainage from the burning block. Though low in elevation, it is on a road and has a good view of one side of the block. A scout is located on the opposite hillside to report progress on the south side of the fire. All ignition, control, and equipment crews are equipped with two-way radios for communication with the scout and fireboss.

The relatively wide spacing of ignition lines is based on an assumed continuous mantle of fuels. The time elapsed between ignition of each successive line depends on the rate of spread. The sequence of ignition was planned to maintain a central convection column. Line 2 should therefore be completed before the fuels ignited along line 1 are burned out. Lines 3, 4, and 5 should be ignited while the internal fire is still burning.

Figure 2C illustrates an alternative ignition pattern. The center is ignited first, as before, but each face is fired at a different time. Note that the northeast-facing slope is ignited immediately after the center; then the northwest, southeast, south, and west, in that order. This sequence depends on appropriate moisture, temperature, and relative humidity. Too, the cool aspects must be fired early in the afternoon, and the normally hotter, drier aspects lighted later in the day. The outside edges of the block are ignited as each numbered line reaches the bottom of the hill.

The ignition pattern in figure 2C permits burning of scattered, low-volume fuels, which might be impossible in a pattern such as figure 2B. Fewer pieces of equipment are required for the pattern in 2C, indicating an easier burning job. Also, a different control point is shown on this map to point out that alternative placements were suggested during the interviews. Some firebosses prefer to be at the spot where control difficulty is anticipated; others prefer to roam about the block. About half of the men planning this burn were inclined to move the fireboss to correspond with ignition and control activity.

Block II

This block includes the lower portion of a draw. Particular attention should be given to the saddle on the western edge and to the long stretch of outside fireline with timbered stands above. This example of a complex situation demonstrated some of the special problems faced by burners in the field.

Figures 3B and 3C illustrate the caution with which respondents approached the planning of block ignition. These maps show two methods of burning small segments at the head and uphill sides of the draw. Again, 75 percent of the men favored the burning plan shown in figure 3B. Bulldozers were called for on both plans to fight possible escapes. Many suggested that the outside firelines be prepared as roads suitable for four-wheel-drive tank trucks.

On both patterns, ignition crews were to proceed slowly downhill from the upper reaches of the block. Quite a few respondents wished to burn out the upper strips at night before igniting the lower portion of the block. In any case, several hours would be consumed by the cautious addition of small increments of fuel as burning progressed downhill.

Erratic winds near the saddle might contribute to control problems. Accordingly, the southeast-facing hillside was also planned for slow downhill ignition.

The fact that three different exposures are represented on this block makes timing of ignition very difficult. The pattern shown in figure 3C requires fuels on different faces to be of about the same moisture content. In this pattern, control crews above the block would ignite the outer edges as line 1 was fired.

The fireboss at the control points located on both maps can observe the whole block, although smoke would probably obscure his view of the upper boundary at times when control would be critical. It is essential that control crews on the upper fireline be equipped with radios in order to notify equipment operators and other crews of threatened escapes.

The danger of fire spreading rapidly up the draw rules out a center-ignition pattern. The slow backfires indicated for both plans would undoubtedly make the 80 acres in this block more costly to burn than the 120 acres of the first block.

Block III

The block illustrated in figure 4 has been reasonably well laid out. The west boundary is slightly over the top of a major ridge, and both north and south edges are without serious overhang of uncut fuels. Note that the north boundary follows the top of a spur ridge.

As in the other blocks, three out of four of the respondents recommended the first alternative: a simple ignition pattern shown in figure 4B. Both sides of the internal roads are ignited as burning progresses downhill. The upper strip is ignited along lines 1 and 2, followed by firing of the west edge, which is a short distance over the crest of the ridge. Subsequent ignition follows the road. Note that the north and south boundaries are not ignited until the adjoining central portion of the block is afire. This tends to draw the flames away from adjacent stands. Crew 4 would start ignition as crew 3 rounded the upper switchback.

Figure 4B shows tankers at the intersections of the two upper roads and the fireline, and a bulldozer on the ridgetop. It is rare to find a bulldozer assigned to a burn of this size. The control point on this map is located on the northeast corner of the block to place the fireboss close to operations.

Figure 4C illustrates an internal ignition pattern for this block. After the convection column is well developed, crews start from the northwest corner and ignite both north and west edges of the block. Ignition line 3 serves to reinforce the central column and draw it downhill.

Lines 4 and 5 complete the circuit. Number 4 crew should begin its downhill ignition line when crew 3 is about halfway across the block. Line 5 should be ignited after crew 3 has completed its line. Crews 4 and 5 should reach the northeast corner of the block at the same time.

PLANNING FOR THE FUTURE

The use of fire as a land management tool is expanding rapidly. Each year different applications are conceived, a greater acreage is burned, and new techniques are put into practice. New men must be trained to assume leadership in a growing program of prescribed burning. The problems of burning under less than optimum fuel and weather conditions urgently require solution.

The respondents were asked to comment on the future of prescribed fire in the Intermountain West. Their answers to questions on how new men should be trained and how to meet the challenge of an expanding program of prescribed burning are presented in the following sections.

Training New Men

Almost all respondents recommended training through direct contact with the planning and execution of actual fires. On-the-ground training should include visits to the fires of nearby management centers. A few men suggested that trainees be temporarily assigned to burning operations in different parts of the country. The majority of respondents believed that new men learned more by watching burns than by participating in them.

About half of those questioned felt that wildfire experience is useful in prescribed burning. A few men disagreed. The latter group contended that objectives and methods are different in wildfire situations and that there is little opportunity on wildfires to observe the patterns of fire behavior that interest prescribed burners.

Forest management specialists without experience in fire control are using prescribed burning more frequently than in the past. Silviculturists, wildlife biologists, range managers, and entomologists require additional knowledge if they are to make the best use of fire in their work. While fire control specialists will continue to assume major responsibility for burning programs, they can expect that other groups will become more closely involved in setting objectives and planning for prescribed fires. Seminars and training classes on prescribed burning should have high priority in the future. At these sessions, personnel from the several disciplines concerned with using fire can discuss and coordinate plans for the development of their programs.

A Larger Program

How can we efficiently burn a greater acreage? Forty-eight percent of the respondents recommended burning in summer as well as in autumn. Many periods in July, August, and early September are suitable for prescribed fires. Night burning coupled with aggressive mopup the following day was recommended for this season. Summer fires would burn more completely than equivalent burns in the autumn. No one suggested that fires be ignited during periods of high fire danger, but many felt that meteorological conditions were more appropriate for burning in summer than during other times of the year.

About 13 percent of the respondents were in favor of adding a spring burning season. They realized that not all blocks are suited to spring fires, but felt that some of the autumn load could be transferred.

Eight percent of the men suggested that highly specialized crews conduct burns on several administrative units. Eleven percent urged that larger burning blocks be planned to include the same acreage in fewer prescribed fires.

No single solution is available to forest managers facing an enlarged burning program. However, spreading the workload to seasons other than the autumn is the obvious first step.

SUMMARY

The study reported in this paper summarized the experience and opinions of 62 prescribed fire practitioners. The men participating had accumulated over 700 seasons of prescribed burning in all. Most of this experience was gained in the forests of the Intermountain West. Personnel from State, private, and Federal organizations contributed their knowledge during formal interview sessions.

Preparations for Burning

Most prescribed burning has the dual purpose of hazard reduction and site preparation on blocks from which merchantable timber has been harvested. Sometimes logging slash and noncommercial stems are broadcast burned where felled; on other occasions this fuel is hand- or machine-piled, or windrowed by bulldozers. Piled logging slash is usually burned late in the autumn. Broadcast burns are typically scheduled soon after the summer wildfire season is past.

Broadcast-burning blocks range in size from 10 to 400 acres. Optimum size for economic operations was judged to be between 100 and 200 acres.

Layout of the block in relation to topography and adjacent hazards is important to successful burning. Good layout requires a minimum of fireline for the enclosed area, uphill boundaries slightly over ridgetops, and reasonably straight upslope edges. Acute corners and doglegs in the outer fireline are potential trouble spots. Compromises in block layout and size are often necessary due to management needs and the realities of fire behavior.

Firelines are typically constructed by using bulldozers equipped with straight blades. One or two blade widths are usually enough to contain a prescribed fire. A continuous line of mineral soil should surround a burning block, but if soil is mixed with fuels moved by bulldozers, the mopup and control job is increased. Slash remaining outside the firelines can harbor sparks and interfere with control action.

Most respondents preferred to fell all trees larger than 4 inches in diameter on burning blocks before the fire. Shaggy-barked and rotten snags should be felled within the fireline and for a distance of about 1 chain outside the block. Noncommercial trees and snags, when felled, help create the desired uniform fuel bed.

When to Burn

Slash fuels require 1 or 2 months of warm, dry weather to cure before burning. Broadcast fires are easier to plan and conduct if burned while needles remain on the branches. For most species, this means that fires should be scheduled within 2 years of harvest cutting. Fuels without needles can be successfully burned if they are bunched in piles or windrows.

Sixty-two percent of the men interviewed preferred to have less than 1 inch of rainfall on the block before burning it in autumn. North and east aspects and blocks at high elevations should be burned prior to burning south- and west-facing blocks. Hazard-reduction objectives can be met by burning warm hillsides at lower elevations in the spring. Mopup must be thorough after spring fires.

Both early morning and late afternoon are favored times for burning. As autumn progresses, some blocks must be burned during the hottest part of the day. Burning hours vary for different objectives and fuel conditions. Ignition time should be determined by the job, not by the clock.

Fuel moisture sticks have been placed on blocks to help decide when to burn. The recommended range for burning is from 6- to 15-percent moisture content.

Relative humidity greatly influences moisture content of fine fuels and thereby influences the behavior of prescribed fires. A range of from 10- to 50-percent relative humidity is suitable for starting fires. Hygrothermographs are important tools in predicting daily changes in relative humidity. They should be placed on a block a week or two prior to burning to help estimate the time of diurnal rise in humidity.

Sixty-five percent of the respondents liked to burn plots when wind velocity was 10 miles per hour or less. Most preferred calm air for prescribed burning. A few men liked a steady, low-velocity wind to minimize the possibility of fire whirls. Clear, cool weather, when smoke columns rise straight up to high altitudes, was preferred for prescribed burning. Most respondents made use of special fire weather forecasts prepared by fire-weather specialists at Weather Bureau stations throughout the region.

Burning

Plans for prescribed fires require detailed maps that show topographic and cultural features, placement of men and equipment, and proposed patterns of ignition. Ignition and control crews should be familiar with these plans before the fire. Crews should also be advised of the fire's progress and changes in ignition plans. Mopup and patrol action after the fire are essential to prevent escapes at a later time.

Ignition devices should be selected for speed and flexibility in lighting many kinds of fuels. Burning crews can make use of several kinds on different fires.

Both strip and center ignition patterns are used by crews in the Intermountain area. A strong, central convection column tends to make burns more efficient and to reduce escapes.

The problems of controlling prescribed fires are simplified when: (1) The size of control crews is related to the expected difficulty of burning each block; (2) good block layout reduces the possibility of escapes; and (3) a strong central convection column draws flames toward the center of the burn.

Respondents were asked to plan the ignition sequence and placement of equipment in three hypothetical burning blocks. Six different solutions are presented in the body of this paper.

Future Needs

Training new men in prescribed burning techniques requires both field experience, and formal classes and seminars on the subject. Future programs will necessitate a greater exchange of knowledge between fire control personnel and other specialists who use fire in forest and range management.

Burning during spring and certain summer periods can reduce the backlog of unburned blocks and allow increased acreage to be burned each year.

APPENDIX

SURVEY PARTICIPANTS

Forest Service Personnel

Harold E. Anderson
Robert J. Beaubier
Dave R. Brown
Marvin H. Combs
Frederick F. Cougill, Jr.
Floyd R. Cowles
Frederick A. Dorrell
Ralph R. Dyment
Orville E. Engelby
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Samuel S. Evans, Jr.
E. Maurice Fickes
Alvin J. Flory
Andy O. Fossum
William J. Fredeking
Lawrence D. Glover
Hubert Hanson
Louis F. Hartig
John L. Hautziner
Theodore R. Hay
Robert J. Henderson
H. Reid Jackson
John W. Johnson
Henry L. Ketchie
Theodore W. Koskella
Henry F. Kottkey
David R. Kyle
Richard E. Leicht
John R. Lyman
Fred H. Mass
Robert J. McCarthy
J. Frank Meneely
Ross P. Middlemist
Dan V. Montgomery
Wayne S. Newcomb
Herbert M. Oertli
Earl W. Parks
Homer W. Parks
Clemens J. Pederson
Neil Peterson
Joseph M. Pomajevich
J. Everett Sanderson
William B. Sendt
Clifford T. Solberg
Ralph Space
Clinton F. Spindler (deceased)
John Sudnikovich
Merrill E. Tester
Gustav A. Verdal
Alfred W. Walter
Hubert B. Ward
Donald V. Williams
Floyd E. Williams
Alvis B. Young
Kenneth I. Young
Ulrich H. Zuberbuhler

State and Private Organizations

Ernest B. Corrick	Anaconda Forest Products
A. B. Curtis	Clearwater Timber Protective Assn.
Richard D. Griffith	St. Regis Paper Company
Ralph Hanson	Blackfoot Forest Protective Assn.
Milton O. Koppang	Clearwater Timber Protective Assn.
Carl Managhan	Montana State Forester's Office
Edwin A. Ring	Idaho State Forester's Office
Herman Schultz	Montana State Forester's Office

INTERVIEW QUESTIONS

1. What were the purposes of the prescribed fires?

   a. Are there differences in procedure of timing depending on purpose?

   b. If so, expand each separately per below:

2. How can the fuels be described? How large are the areas to be burned?

   a. Classify by weight per acre, size classes, species, age, depth, and disposition (scattered or continuous).

   b. Does procedure or timing differ depending on fuels?

   c. If so, expand each separately per below:

3. What fuel preparations are necessary?

   a. Felling noncommercial trees. When?

   b. Spraying brush. How recommended? When?

   c. Time required for curing — maximum, optimum, minimum?

   d. Fireline construction.

      (1) Widths recommended for different topographic conditions: flat, 50 percent, 90 percent, V-shaped canyon, ridgetops.

      (2) Adjacent-stand treatment recommendations. Felling snags what distance? Others?

4. Time of burning.

   a. Are there differences in timing due to exposure, slope, and elevation? If so, expand each separately per below:

   b. Time of year.

   c. Time of day.

   d. Recommended fuel moisture content in burn area.

   e. Difference between stick weight in the open and adjacent forest.

   f. How much precipitation do you feel is necessary before autumn burning?

5. What weather conditions are suggested prior to fire? During fire? If a range of weather conditions is possible, what is acceptable for each of the following?

   a. Wind — maximum, optimum, minimum?

   b. Temperature — maximum, optimum, minimum?

   c. Relative humidity — maximum, optimum, minimum?

   d. Synoptic pattern — optimum, marginal?

6. Do you use special fire-weather forecasts?

7. Ignition procedures:

   a. What devices do you use?

   b. What determines firing pattern — center ignition, strip ignition?

   c. What safety measures are needed?

   d. What time sequence is recommended for each kind of firing?

8. What does a well-prepared site look like? Can a prescribed fire be too hot?

9. Control and mopup:

   a. Why have some of your fires exceeded their bounds?

   b. For each reason, how can it be prevented?

   c. What mopup operations do you plan?

10. How should new men be trained? How are we going to accomplish the larger burning job ahead?

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Project headquarters are also at:

Boise, Idaho
Bozeman, Montana (in cooperation with Montana State University)
Logan, Utah (in cooperation with Utah State University)
Missoula, Montana (in cooperation with University of Montana)
Moscow, Idaho (in cooperation with the University of Idaho)
Provo, Utah (in cooperation with Brigham Young University)

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